# A New Copepod of the Genus *Calanus* from the Northeastern Pacific with Notes on *Calanus tenuicornis* Dana[1]

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WHILE ENUMERATING COPEPODS from net hauls made in 1949 and succeeding years off the California coast in connection with the California Cooperative Oceanic Fisheries Investigation (CCOFI), it was observed that specimens with characters agreeing with those given in the literature for *Calanus tenuicornis* Dana were of two types. One form, limited to the southern portion of the area investigated, had a longer and narrower body and relatively longer appendages. The other, more stubby, form had a wider distribution, with maximum numbers to the north. The problem of whether these two forms are environmentally determined or whether they differ genetically on the specific or subspecific level invited investigation. The results of this study, presented herein, have led to the conclusion that the more stubby form is Dana's *C. tenuicornis*, and the elongate form is a new species.

*Calanus tenuicornis* was first described by Dana (1853: 1069) from the Central North Pacific. His description was brief, dealing chiefly with the first antenna. He figured (1855, pl. 73, fig. 10 a, b) a dorsal view of the adult female with the first antennae attached and detail of the distal end of the first antenna. Giesbrecht (1892, pls. 6–8) provided several additional illustrations. Figures published by most authors following Giesbrecht (van Breemen, 1908, fig. 8, a–d; Pesta, 1920, fig. A, 3; Rose, 1933, fig. 12; Farran and Verwoort, 1951, fig. 3, a, h) are taken from Giesbrecht's illustrations. Esterly (1905, fig. 3, a, b) and Brodsky (1950, fig. 24) provided additional original figures. Since the appendages of *C. tenuicornis* are identical with those of the new species (Figs. 1, 2) in all details of segmentation and armature, its has not been deemed necessary to illustrate them here.

A complete synonomy for *C. tenuicornis* is given by Verwoort (1946: 22) and need not be repeated. Additional references to this species are those of Mori (1937: 16, pl. 3, figs. 9, 10, pl. 4, figs. 1–3), Wilson (1942: 195; 1950: 269) Brodsky (1950: 95–97, fig. 24), Farran and Verwoort (1951: 3, fig. 3a, 3h), Rose and Vaissiere (1952: 116), and Yamazi (1953: 198).

*C. tenuicornis* may be distinguished easily from other previously known species of *Calanus* by the elongate first antennae and the reduced size of the outermost setae of the furcae. Elongate first antennae are also characteristic of *C. gracilis* Dana and *C. robustior* Giesbrecht, but both these species differ from *C. tenuicornis* in having a strong hooked spine on the anterior aspect of the second basis of the first swimming legs. Furthermore *C. tenuicornis* is much smaller than the other species (*tenuicornis*, 1.5–2.4 mm.; *gracilis*, 2.3–3.3 mm.; *robustior*, 3.0–3.8 mm.). In both *C. gracilis* and *C. robustior* the long setae on the

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posterior margins of segments 23 and 24 of the first antennae are distinctly segmented even in the early copepodite stages; in *C. tenuicornis* there is no trace of segmentation. Finally, in the two larger species, the proximal part of the outer margin of the third exopodal segment of the second to fourth swimming legs of the male is serrate; in *C. tenuicornis* these margins are smooth.

Sars (1925: 7) erected a new genus, *Neocalanus*, which he did not define, to include *tenuicornis*, *gracilis*, and *robustior*. Although modern authors differ as to the validity of *Neocalanus*, almost all are agreed that *tenuicornis* should not be placed in it. *Neocalanus* was first defined by Verwoort (1946: 39); his definition, which includes the hooked spine of the first swimming legs and the serrations on the second to fourth swimming legs, definitely excludes *tenuicornis*.

*C. tenuicornis* is widely distributed in tropical and temperate waters, although it is not ordinarily taken in very large numbers. Verwoort (1946) has summarized distribution records from the literature. It is sparingly distributed throughout the Atlantic from about 52° N. to 20° S., with northern record from the Faroe Banks. It is found in all parts of the Mediterranean. In the Indo-Pacific it ranges from about 42° N. to 52° S. Wilson's (1942) records, not mentioned by Verwoort, show it to be widespread in the Eastern Pacific, within about the same latitudinal boundaries. It is not usually a common species in the East Indies. Cleve (1904) records it from both east and west of South Africa. Ordinarily it is an epiplanktonic form.

## ***Calanus lighti*** new species

Figs. 1, 2

This species is named in honor of the late S. F. Light of the University of California, Berkeley.

ADULT FEMALE: Length, excluding furcal setae, 2.32–3.08 mm. Body form similar to *C. tenuicornis*, but longer and more slender in appearance. Ratio of length to depth of cephalothorax about 6:1 as opposed to 4.5:1 in *C. tenuicornis*. Head with more flattened dorsal slope (lateral view) than in *tenuicornis*. Head separated from first thoracic somite by weakly developed suture. Posterior border of head raised into a small, slightly backward-curved process in dorsal midline. Thorax about one fourth longer than head; second and fourth somites each with two pairs of setae on either side of median dorsal line, anterior pair longer; third somite with two pairs of equal-sized dorso-lateral setae; fifth somite rounded posteriorly, slightly overlapping genital somite. Genital somite produced into somewhat flattened hump ventrally, less produced than in *tenuicornis*. Abdominal somites much longer in proportion to their depth than in *tenuicornis*; somite 2 about one third longer than somite 3 (only one fourth longer in *tenuicornis*). Furcae about 2.5 times as long as wide; the four apical setae very long, especially the next to innermost one, which is about twice as long as the others; lateral setae very short.

First antennae more than twice as long as body; segments 3, 7, 14, 18, 21, and 24 bear elongate setae anteriorly; segments 23 and 24 each bear a very long feathered seta on the posterior surface.

Setae of mouth parts, especially those of the terminal segments, very long. Setae of exopod of first maxilla very long, feathered, and pigmented.

First swimming leg with triangular projection on proximal part of posterior surface of first segment of exopod. Posterior part of distal margin of first segment of endopod produced into a number of minute linear processes in the specimen drawn, not in other specimens examined. Medial margin of first basipod of fifth swimming leg smooth, without setae.

ADULT MALE: Length, excluding furcal setae, 1.90–2.68 mm. Body a little shorter and less slender than in female. Head more rounded in lateral view. Third thoracic somite with two pairs, fourth somite with one pair

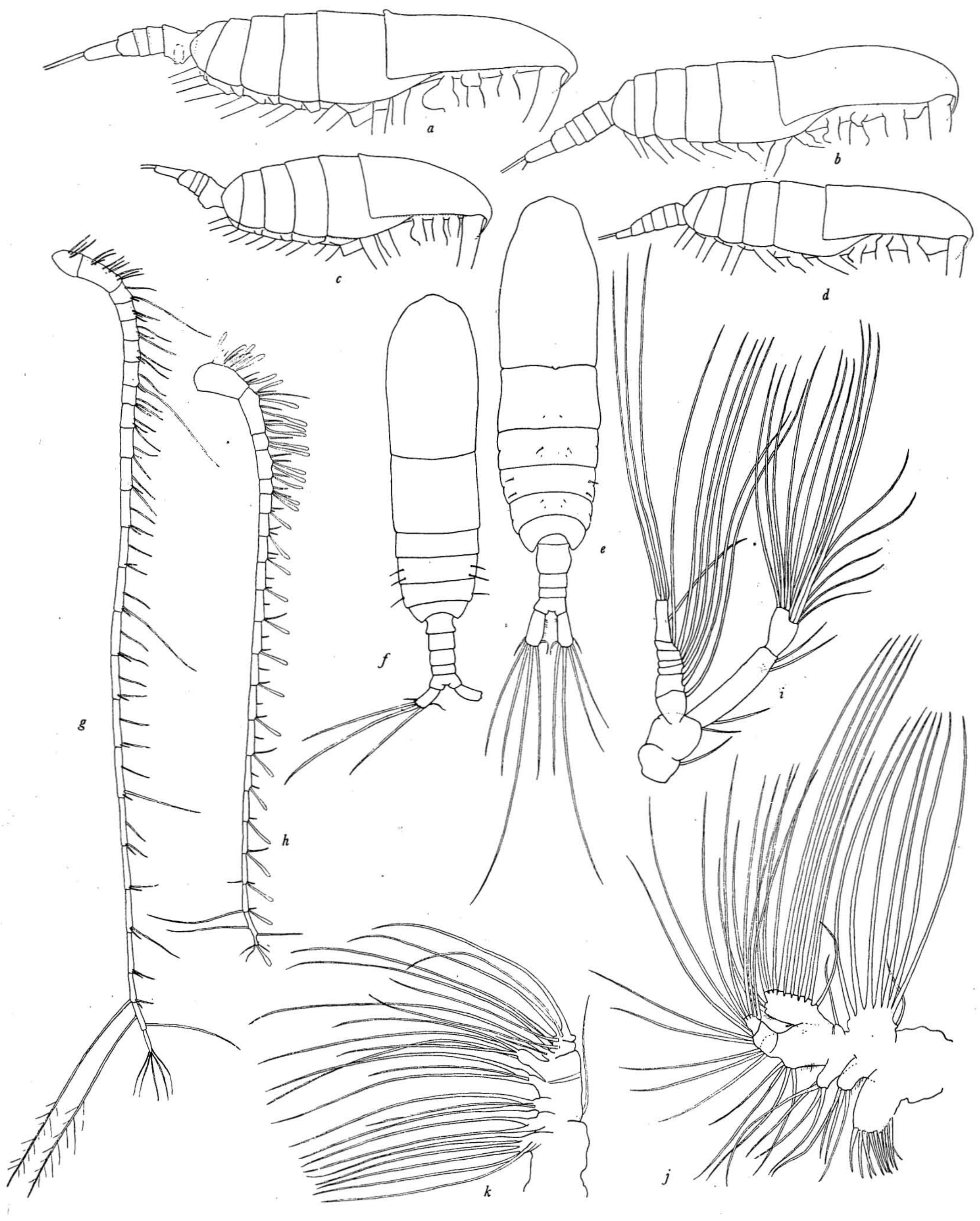


FIG. 1. *a–b, e–k, Calanus lighti* n. sp.; *c–d, Calanus tenuicornis* Dana. *a*, Female, lateral view; *b*, male, lateral view; *c*, female, lateral view; *d*, male, lateral view; *e*, female, dorsal view; *f*, male, dorsal view; *g*, first antenna, female; *h*, first antenna, male; *i*, second antenna, female; *j*, first maxilla, female; *k*, second maxilla, female.

of dorso-lateral setae, larger than those of the female. Furcae usually widely divergent.

First antennae about 1.5 times as long as body; segments 1–2, 3–5, 7–8, and 24–25 fused.

Mouth parts reduced, some of setae reduced in size or absent. Second antennae without setae on proximal segment of endopod. Gnathal lobe of mandible much smaller and more weakly chitinized than in female; teeth only slightly developed; terminal segment of endopod with only nine setae. First maxilla thinly chitinized in comparison with that of female; spines on gnathal lobe reduced.

Fifth swimming legs as in *C. tenuicornis;* no setae on inner margins of exopods; distal segment of left exopod pyriform, with slender terminal spine.

TYPES: The types, all from CCOFI cruises, have been deposited in the United States National Museum. They are listed in Table 1.

Over 100 specimens of *C. tenuicornis* from CCOFI cruises have been added to the United States National Museum collections.

Eight paratypes of *C. lighti* and 11 specimens of *C. tenuicornis* have been deposited at the Scripps Institution of Oceanography, La Jolla, California. Seven paratypes of *C. lighti* and 18 specimens of *C. tenuicornis* have been sent to the Allan Hancock Foundation, University of Southern California.

REMARKS: *C. lighti* is most readily distinguished from *C. tenuicornis* by the shape of the body in lateral view. In addition to the generally more slender and elongate form, the new species is characterized by the more pronounced dorsal elevation at the posterior margin of the head and the ratio of length to depth of the abdominal somites. The males of the two species are less easily distinguished than the females. Where the two species occur together the differences in size and form are readily discernible in both sexes. If only one species is present, it can be assumed that the males are conspecific with the usually much more numerous females.

The posterior process on the first segment of the exopod of the first swimming leg (Fig. 2f) apparently has not been recorded previously from calanoid copepods, probably because of its inconspicuousness. It is, however, not limited to the species treated in this paper, for I have observed a similar, less pronounced process in *Calanus gracilis*, *C. robustior*, *C. finmarchicus*, and *Undinula vulgaris* but not in *Calanus minor*. Possibly it is of rather widespread occurrence. A somewhat similar process on the posterior aspect of the second basal segment of the first swimming leg is reported by Sewell (1947: 165, text fig. 49) for members of the family Metridiidae.

Without exception, the furcae in all the specimens of *C. tenuicornis* and *C. lighti* that I have examined contained a number of

TABLE 1

DATA ON TYPES OF *Calanus lighti* SP. NOV.

| | CRUISE | STATION | | | USNM NO. |
|---|---|---|---|---|---|
| Holotype ♀, 1 | 5 | 1008 | 28° 50′ N | 121° 19′ W | 97109 |
| Allotype ♂, 1 | 5 | 1008 | 28 50 | 121 19 | 97110 |
| Paratypes, 16 | 5 | 1008 | 28 50 | 121 19 | 97111 |
| 66 | 6 | 807 | 32 05 | 124 55 | 97112 |
| 20 | 9 | 1204 | 26 16 | 117 03 | 97113 |
| 88 | 9 | 1009 | 28 31 | 121 52 | 97114 |
| 3 | 4 | 1105 | 28 04 | 118 36 | 97115 |
| 5 | 20 | 120.110 | 25 33 | 119 44 | 97116 |
| 50 | 9 | 1011 | 27 56 | 122 59 | 97117 |

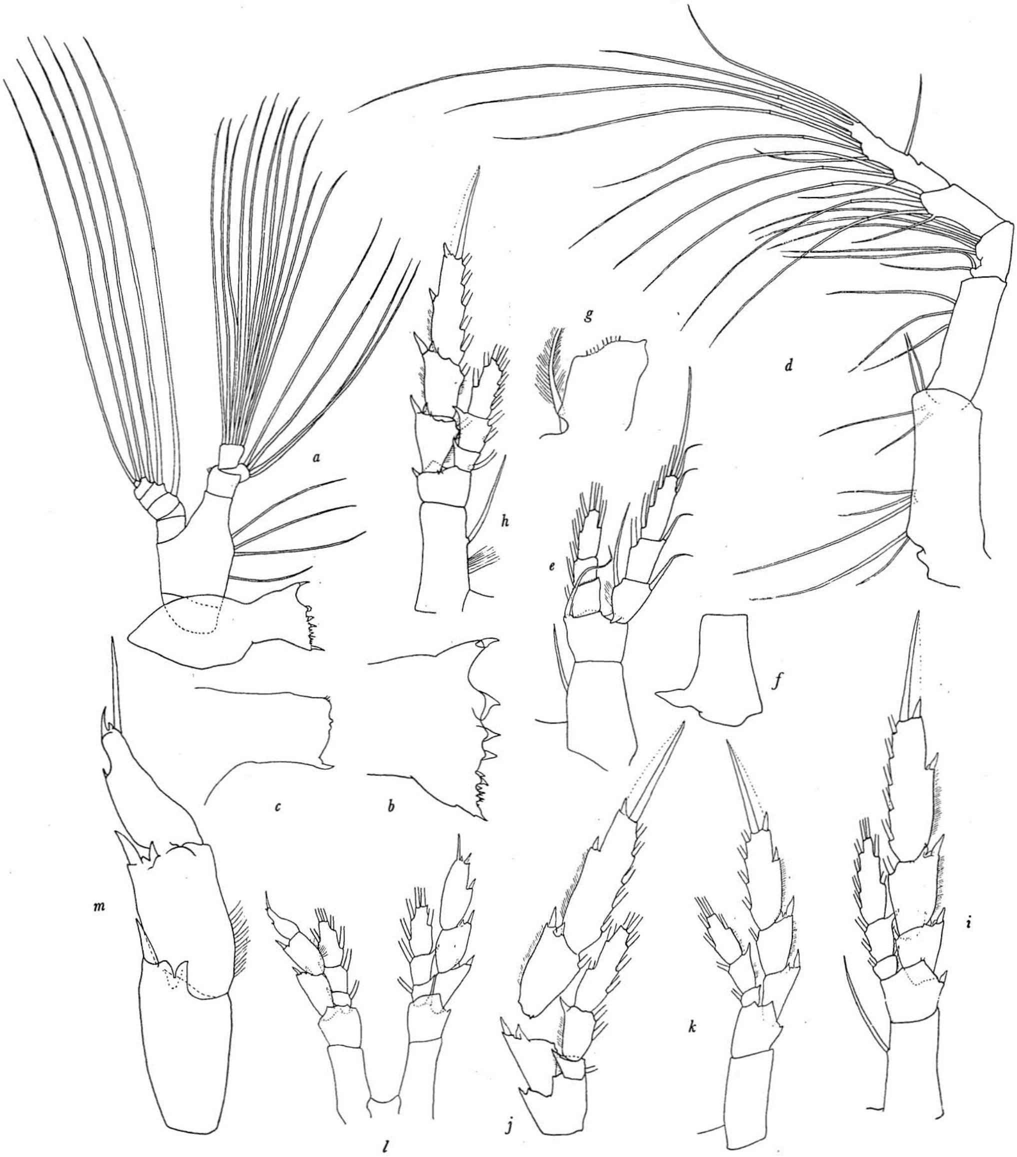


FIG. 2. *Calanus lighti* n. sp. *a*, Mandible, female; *b*, gnathal lobe of mandible, female; *c*, gnathal lobe of mandible, male; *d*, maxilliped, female; *e*, first leg, female; *f*, first segment of exopod of first leg, female, lateral view; *g*, first segment of endopod of first leg, female; *h*, second leg, female; *i*, third leg, female; *j*, fourth leg, female, first basipod not shown, distal part of exopod separated from first segment; *k*, fifth leg, female; *l*, fifth leg, male; *m*, exopod of left fifth leg, male.

TABLE 2

LENGTH OF THE CEPHALOTHORAX IN *Calanus tenuicornis* AND *C. lighti*
(Measurements in Millimeters)

| STATION | *Calanus tenuicornis* DANA | | | *Calanus lighti*, SP. NOV. | | |
|---|---|---|---|---|---|---|
| | Number of specimens | Average | Range | Number of specimens | Average | Range |
| Cruise 6 | | | | | | |
| 107 | 5 | 1.54 | 1.49–1.59 | | | |
| 205 | 13 | 1.54 | 1.47–1.59 | | | |
| 405 | 15 | 1.66 | 1.54–1.81 | | | |
| 605 | 17 | 1.78 | 1.64–1.88 | | | |
| 707 | 12 | 1.66 | 1.47–1.76 | | | |
| 807 | 13 | 1.54 | 1.40–1.81 | 45 | 2.31 | 2.17–2.41 |
| 1011 | | | | 11 | 2.05 | 1.88–2.31 |
| 1107 | 8 | 1.57 | 1.52–1.61 | 15 | 2.02 | 1.88–2.12 |
| 1201 | 27 | 1.74 | 1.64–1.88 | | | |
| 1205 | 14 | 1.64 | 1.54–1.71 | 100 | 2.07 | 1.90–2.27 |
| Cruise 9 | | | | | | |
| 1009 | 28 | 1.54 | 1.37–1.61 | 90 | 2.01 | 1.83–2.14 |

spherical refractile bodies. These represent a protozoan parasite which is probably responsible for the erosion of the furcal setae noticed in all specimens examined. It has been practically impossible to find specimens with all the furcal setae intact, and I have not found a single male with an undamaged next-to-outermost seta. These parasites are so characteristic that they can almost be used for separating these two species from other planktonic copepods.

## SIZE RELATIONSHIPS

The body length of *C. tenuicornis* is given by several investigators (Dana, 1853; Giesbrecht, 1892; Esterly, 1905; Farran, 1929; Rose, 1933; Verwoort, 1946). Comparative measurements of the body lengths of *C. tenuicornis* and *C. lighti* are:

| | FEMALE *mm.* | MALE *mm.* |
|---|---|---|
| *C. tenuicornis*, from literature | 1.8 –2.1 | 1.5 –1.95 |
| *C. tenuicornis*, CCOFI specimens | 1.64–2.39 | 1.71–2.02 |
| *C. lighti*, CCOFI specimens | 2.32–3.08 | 1.90–2.68 |

In Table 2 are given the cephalothorax lengths of 413 specimens of *C. tenuicornis* and *C. lighti*, mostly from CCOFI Cruise 6 (August, 1949), with one station from Cruise 9 (November, 1949). It is noteworthy that at the five stations where both species were taken there was no overlap in size at any one station. The absence of intermediate forms is evidence that interbreeding between the two copepods does not occur.

## DISTRIBUTION IN THE NORTHEAST PACIFIC

Figure 3 shows the distribution of the *Calanus tenuicornis* and *C. lighti* encountered during four CCOFI cruises. At the stations shown, oblique hauls of 20 minutes duration were made with one meter plankton nets from a depth of about 70 meters (140 meters in Cruise 20) to the surface. Details of net construction and methods by which the hauls were made are given by Ahlstrom (1948, 1952). *C. tenuicornis* was widely distributed over the area covered, while *C. lighti* was limited to the stations south of Point Conception. It is interesting to note that *C. lighti* extends furthest north at the outermost stations, so that the northern boundary of its range roughly parallels the surface isotherms. This sort of distribution is very common among certain planktonts in this region and has been observed (unpublished) by students of several different groups who are working on the collections of these cruises. We do not have here a case of a northern form being replaced to the south by a southern form, but apparently of a widely distributed species (*C. tenuicornis*) and a species with restricted distribution (*C. lighti*). Figure 4 shows the stations occupied during a cruise made by CCOFI in cooperation with the Inter-American Tropical Tuna Commission. No counts were made of the copepods taken at these

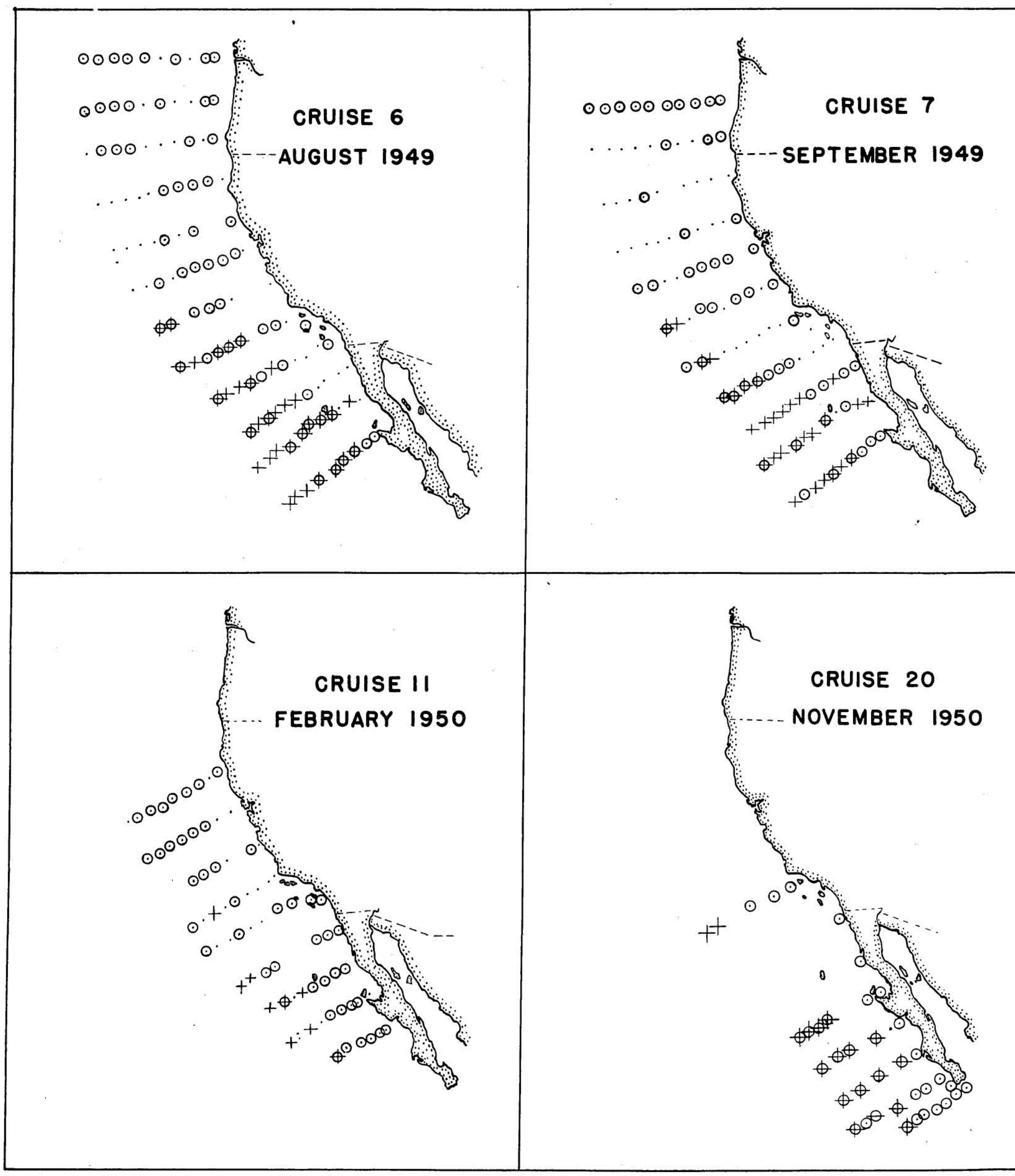


FIG. 3. Distribution of *Calanus tenuicornis* and *C. lighti*, from four CCOFI cruises. Dots, stations occupied; circles, *C. tenuicornis;* plus marks, *C. lighti.*

stations, but they were examined to see whether either *C. tenuicornis* or *C. lighti* was present. In all samples examined *C. tenuicornis* was present, but no specimens of *C. lighti* were found. *C. lighti* appears to be limited to oceanic waters off the coasts of southern California and Baja California, while *C. tenuicornis* occurs in neritic as well as oceanic waters, and has a much greater north-south range. Further information is needed concerning the distribution of *C. lighti* to the west of the area from which I have examined plankton samples.

The type specimen of *C. tenuicornis*, unfortunately no longer extant, was taken at 40° N., 157° W. To assist in determining which of the two forms from the CCOFI cruises was Dana's species, some of the plankton samples from stations of the "Northern Holiday" cruise of the Scripps Institution of Oceanography in 1951 were examined. At the following stations only the smaller form (*C. tenuicornis*) was taken; no *C. lighti* was found in the sample:

| "NORTHERN HOLIDAY" STATION | LATITUDE | LONGITUDE |
|---|---|---|
| 45 | 42° 15′ | 155° 36′ |
| 46 | 41° 20′ | 155° 20′ |
| 47 | 40° 09′ | 155° 03′ |
| 48 | 39° 18′ | 154° 38′ |
| 49 | 38° 30′ | 154° 25′ |
| 50 | 37° 28′ | 154° 12′ |
| 56 | 28° 06.5′ | 151° 25′ |

This makes it highly probable that the smaller form is conspecific with Dana's specimen. The more restricted range of the larger form (*C. lighti*), which appears to be limited to an area not yet thoroughly explored, perhaps explains why it has not been discovered previously.

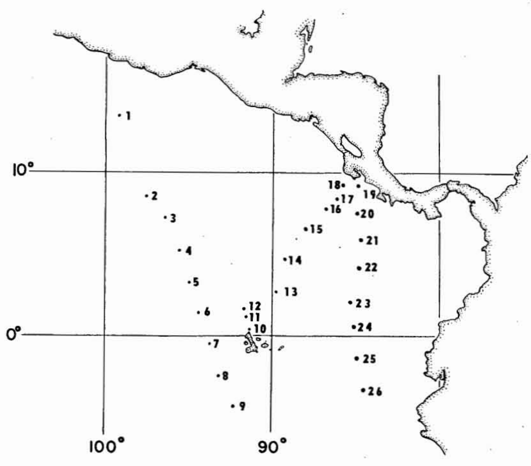


FIG. 4. Station positions of the CCOFI-Inter-American Tropical Tuna Commission Cruise, January 1–March 4, 1953 in the east-central Pacific. *Calanus tenuicornis* was present in all stations; *C. lighti* was found at none.

## DISCUSSION

It might be argued that since the two forms discussed herein differ only in body size and conformation they do not merit specific distinction. However, the available evidence indicates that they must be treated as different species, rather than as subspecies or environmentally determined forms of a single species.

1. Although the geographic range of *tenuicornis* overlaps extensively the more restricted range of *lighti*, each species is characterized by a distinct geographic range.

2. The absence of specimens intermediate in size or in body form at stations where the two species occurred together is evidence that the two copepods are reproductively isolated.

3. The two species differ in their pigmentation. Preserved females of *C. lighti* have spherical spots of red pigment in the first antennae. These were not found in any preserved female of *C. tenuicornis*, or in five living specimens brought to the laboratory from about three miles off Point Loma, California.

It is possible that the two forms will be found to intergrade in other regions where their ranges overlap. Such a discovery might make it necessary to reduce *C. lighti* to subspecific rank. For the present, however, it is given specific status.

It is well known that the size and form of both marine and fresh-water copepods can be modified by environmental influences, especially temperature. When reared in the laboratory at low temperatures, fresh-water copepods (*Cyclops*) tend to reach a larger size (Coker, 1933) and to have longer and narrower furcae (Coker, 1934). Steuer (1925, 1931, 1932) has erected "forma" and geographic races for several species of marine copepods; the larger forms were from the colder parts of the geographic range or from deeper, hence colder water. Recently, Deevey (1952) reviewed the subject of seasonal variations in size in marine copepods; her own studies showed an inverse correlation between temperature and size in *Centropages typicus* and *C. hamatus*.

Because of these findings, it is necessary to consider the possibility that the two forms of *Calanus* (*tenuicornis* and *lighti*) are actually ecophenotypes. If such were the case we would expect to find the largest specimens in the coldest water, with a gradual and more or less continuous decrease in size to the south. Instead of this, it has been pointed out that the smaller, more chunky form occurs in both colder and warmer water than the longer, more slender *C. lighti*. Hence it is clear that the two species are not temperature-induced ecophenotypes.

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